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THE REACTION OF PAWNEE AND BLISS TRIUMPH POTATOES TO CERTAIN PHYSIOLOGIC RACES OF *ACTINOMYCES SCABIES*

L. A. SCHAAL

Division of Fruit and Vegetable Crops and Diseases. Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, Fort Collins, Colo.

INTRODUCTION

The reaction of potato varieties to common scab caused by *Actinomyces scabies* (Thaxt.) Güssow, is quite variable. Leach *et al* (1) showed that physiologic races of *A. scabies* are responsible for this variation in severity of scab. Subsequent investigations (2) showed that a large number of physiologic races are present in soils and certain varieties of potatoes are susceptible to a large number of races.

The varieties Pawnee and Bliss Triumph have been found to be susceptible to many races of *Actinomyces scabies* in Colorado. Occasionally Pawnee has been free from scab when grown in soil producing severely scabbed Bliss Triumph. This variation in the resistance of a given seedling or named variety has been noted in certain local areas, and suggests that Pawnee is resistant to certain races common in Colorado soils that cause severe damage to Bliss Triumph.

The production of variants in physiologic races of *Actinomyces scabies* occurs quite commonly in culture media (2) and there is little doubt that variants are also produced by the organism while growing as a saprophyte in the soil and also as a parasite on the potato tuber. Several

culturally different races of *A. scabies* have been isolated from a single pustule. Either a mixture of races was responsible or mutants occurred in the pustule. Increase in the pathogenicity of these variants has not been demonstrated, but is considered to be quite possible.

It has been demonstrated that certain varieties of potatoes differ in their reaction to the various races of the scab organism present in the soils of Colorado. Bliss Triumph, Pawnee, Irish Cobbler, Katahdin, and Rural New Yorker all became scabby in certain soils. In other soils all but Pawnee were free from scab. In a few cases, Irish Cobbler and Bliss Triumph were found to be completely susceptible and Pawnee free from infection. A difference in pustule type on Pawnee suggests a race of *Actinomyces scabies* that is more or less specific for this variety.

Experimental Data

The variety Pawnee has consistently shown a No. 3, or intermediate, type of scab pustule when grown in the Greeley district of northern Colorado where this variety was developed. In some areas of Colorado and infrequently in the Greeley area a crop of practically scab-free tubers has been grown. Frequently Bliss Triumph grown on the same soil showed a No. 4 or No. 5 type of scab pustule.

Experiment No. 1

The scab organism was isolated from a No. 3 type of pustule common on Pawnee and from a No. 4 type of pustule on Bliss Triumph grown in the same soil. The isolates from these two varieties differed culturally. Culture No. 386, isolated from a No. 3 type of pustule on Pawnee, was grayish white with abundant mycelial growth, and was non-pigment-forming on modified potato dextrose agar. (a)Culture No. 346, isolated from a No. 4 type pustule on Bliss Triumph, was dark gray with abundant aerial mycelium and produced a dark-brown pigment on modified potato dextrose agar. Culture No. 346 had the strong, earthy odor characteristic of some races of *Actinomyces scabies,* whereas culture No. 386 produced a very mild Actinomyces odor or none.

Result of Inoculating Pawnee and Bliss Triumph Tubers with Cultures Nos. 386 and 346

Scab-free seed pieces of both varieties, Pawnee and Bliss Triumph, were surface disinfected in 1-1000 mercuric chloride for 1 hour, washed for 1 hour under running tap water, and planted in sterilized soil in the greenhouse. For each variety four pots were inoculated with culture No. 386 and four with No. 346, at planting time and again when the tubers were forming; two check pots received no inoculum. The inoculum was

TABLE 1—*Cultural characters and parasitic action of Actinomyces scabies isolated from Pawnee and Bliss Triumph tubers in Colorado.*

Experiment	Culture Number	Source of Culture	Color of Mycelium	Pigment Produced in Modified P.D.A.	Actinomyces Odor	Type of Pustule on Pawnee	Type of Pustule on Bliss Triumph
I	386	No. 3 Type of Pustule on Pawnee	Grayish White	None	Weak	No. 3	None
	346	No. 4 Type of Pustule on Bliss Triumph	Steel Gray	Brown	Strong	None	No. 4
II	320	No. 5 Type of Pustule on Pawnee	Grayish White	None	Weak	No. 5	No. 5
	347	No. 5 Type of Pustule on Bliss Triumph	Grayish White	None	Weak	No. 1	No. 5

prepared by scraping the scab organism from colonies grown on modified potato dextrose agar in petri dishes and mixing with sterile water. It was added directly to the soil in the pots. When the plants were mature the tubers were examined for scab pustules.

The first part of table 1 summarizes the effect of these two isolates on Pawnee and Bliss Triumph tubers. Culture No. 386 from a No. 3 type of pustule on Pawnee, produced a No. 3 type of pustule on Pawnee tubers, but no infection on Bliss Triumph. Culture No. 346 from a No. 4 type of pustule on Bliss Triumph produced a No. 4 type of pustule on Bliss Triumph tubers, but no infection on Pawnee tubers. Each of these cultures attacked the variety from which it was isolated, but not the other variety tested.

Inoculation Experiment No. 2

Occasionally a deep No. 5 type of scab pustule is found on Pawnee tubers grown in commercial fields of northern Colorado. Often two types, the shallower No. 3 and the deep No. 5, are found on the same tuber. The No. 5 type often infects the tuber to a depth of 8-10 mm., similarly to the No. 5 type commonly found on Bliss Triumph.

The scab organism was isolated from a No. 5 type of pustule on Pawnee and from a No. 5 type on Bliss Triumph grown in the same soil. Inoculation of sterlized soil was done as previously described in Experiment No. 1. Results of these inoculations are summarized in table 1.

Culture No. 320, isolated from a No. 5 type of pustule on Pawnee, produced a No. 5 type on both Pawnee and Bliss Triumph tubers in this greenhouse test. Culture No. 347, isolated from a No. 5 type of pustule on Bliss Triumph, produced a No. 5 type on Bliss Triumph but a No. 1 type on Pawnee (Fig. 1). These results indicate that a race of *Actinomyces scabies* causing a No. 5 pustule on Pawnee may cause a similar pustule on Bliss Triumph, but that a race causing the deep pustule on Bliss Triumph may not cause a similar deep pustule on Pawnee. Thus Bliss Triumph appears to differ from Pawnee in susceptibility to certain races of *A. scabies*. Differences in odor production and mycelium color in the four isolates studied could not be correlated with parasitism as shown in table 1.

Summary

Bliss Triumph and Pawnee potatoes are commonly infected with scab in Colorado soils; but occasionally Pawnee is found to be free from scab in soils that produce a scabby crop of Bliss Triumph. This suggests that Pawnee is resistant to certain races of *Actinomyces scabies* that may scab Bliss Triumph severely.

(a) Formula for culture medium: Pared potatoes, 300 gm.; dextrose, 5 gm.; agar, 20 gm.; tap water, 1000 cc.

Experiments with four isolates of *Actinomyces scabies* in the greenhouse showed that Pawnee was resistant to two races that caused deep scab on Bliss Triumph; also that a race causing an intermediate type of pustule on Pawnee did not produce scab on Bliss Triumph.

No. 5 Type of Pustule on Bliss Triumph Culture No. 320

No. 5 Type of Pustule on Bliss Triumph Culture No. 347

No. 5 Type of Pustule on Pawnee Culture No. 320

No. 1 Type of Pustule on Pawnee Culture No. 347

FIG. 1. Types of pustules produced on Pawnee and Bliss Triumph tubers when grown in soil inoculated with two races of *Actinomyces scabies*.
Culture No. 347 from a No. 5 type of pustule on Bliss Triumph.
Culture No. 320 from a No. 5 type of pustule on Pawnee.

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A COMPARISON OF *CORYNEBACTERIUM SEPEDONICUM* INOCULA FROM RESISTANT AND SUSCEPTIBLE POTATO VARIETIES

G. H. STARR[1] AND W. A. RIEDL[2]

Wyoming Agricultural Experiment Station, Laramie, Wyo.

Since it was found that ring-rot-resistant potato seedlings commonly carry the causal bacteria, *Corynebacterium sepedonicum*, without showing the usual plant symptoms, there has been some doubt regarding the advisability of distributing such potato varieties to commercial areas. In addition, some workers have found that bacteria were more abundant in resistant varieties than in susceptible ones and have suspected that they might be even more pathogenic.

With this thought in mind, the authors conducted experiments during 1946 and 1947 to determine primarily the relative pathogenicity of ring-rot bacteria carried by resistant and by susceptible potato varieties.

In 1946 the tests were preliminary in scope but they were continued in 1947 on a more extensive basis.

EXPERIMENTAL METHODS

In 1946 one lot of twenty Teton tubers was inoculated with infected Teton tubers by rubbing the cut surfaces of each together until the bacterial ooze was well distributed. Another lot of Teton tubers was inoculated similarly with infected Bliss Triumph tubers and all seed pieces were planted soon after inoculation at the Agronomy Farm, Laramie. In another test, Bliss Triumph tubers were inoculated with ooze from resistant tubers, whereas an additional lot was inoculated with ooze from susceptible tubers. In a like manner, Teton tubers were inoculated with the two types of inocula. Forty seed pieces were inoculated in each lot by rubbing the cut surfaces of the seed pieces with the cut surfaces of infected tubers and later dipping them in a thick suspension of the bacteria just prior to planting.

In 1947 experiments were conducted both at Laramie and Torrington Stations, using bacterial ooze from Bliss Triumph, Red McClure and Teton potato varieties to inoculate these three varieties and, in addition, the Burbank, in all combinations. The tests were made in units of ten tubers each with two replications. These tubers were cut into two seed pieces after which they were inoculated with ring-rot bacteria from the different sources, by rubbing together the cut surfaces of healthy and in-

[1]Pathologist.
[2]Agronomist.

fected tubers. One-half of each inoculated tuber was planted at Laramie, while the other half was planted two days later at the Torrington Station located 140 miles away and 3,000 feet lower in elevation. Another experiment was conducted at Laramie in which resistant varieties and seedlings and susceptible varieties were inoculated in a similar manner with ring-rot ooze taken from susceptible varieties and also from resistant varieties. All were planted in ten-hill units replicated four times.

The seed pieces in all tests gave good germination and stands. Disease readings were made at approximately weekly intervals after ring-rot symptoms began to appear, until September the 11th, at which time the last disease inspection was made.

During the latter part of September, one stem was collected from each hill in the unit, consisting of 20 hills. These stems were put in new paper bags, labeled and brought into the laboratory where they were thoroughly washed and dried of excess moisture. The lower portions of the stems were cut off and the freshly-cut sections were pressed firmly against the glass slide. These smears were later stained and examined microscopically for the presence of bacteria . The scalpels were sterilized thoroughly between each stem cut by first dipping them in mercuric chloride (1:500) for a period of 15 seconds or more, after which they were wiped dry with sterile cotton and heated thoroughly in a Bunsen flame.

The tubers were then harvested from each unit, placed in storage and will be examined again at the end of the storage period.

Experimental Results

In 1946 the results showed that when tubers of the Teton variety were inoculated with ooze taken from tubers of the Bliss Triumph variety, 17 per cent ring rot was found. Similarly, when Teton tubers were inoculated with ooze from infected Teton tubers, 20 per cent ring rot resulted. In another test, when Bliss Triumph tubers were inoculated with ooze from resistant seedlings, 91 per cent of the plants showed ring rot, whereas inoculum from susceptible seedlings yielded 97 per cent ring rot. Moreover, resistant seedlings inoculated with ooze from resistant tubers gave 21 per cent, whereas the inoculum from susceptible seedlings gave 15 per cent ring rot.

In 1947 when susceptible and resistant varieties were inoculated with ooze from both susceptible and resistant varieties, the results were, for the most part, in favor of the susceptible inoculum, both in percentage of plants infected and the severity of plant infection, as will be noted in table 1.

TABLE 1—*The prevalence and severity of ring rot (plant symptoms) on September 7 in three potato varieties inoculated with ooze from susceptible and resistant varieties and planted June 5, 1947.*

Ring-rot Inoculum Used	Varieties* Inoculated and Resulting Ring Rot					
	Red McClure		Burbank		Bliss Triumph	
	Per Cent	Index**	Per Cent	Index**	Per Cent	Index**
Ooze from susceptible varieties	54	1.0	93	2.8	100	3.4
Ooze from resistant varieties and seedlings	40	0.6	65	1.4	100	3.0

*The Teton variety and several resistant seedlings were inoculated but the plant symptoms were so slight that they were not included in this table.

**Index figure calculated showing average severity of plant infection, — 1 = slight, 5 = entirely killed.

Ring-rot infection was equally or more prevalent in all varieties tested when inoculated with inoculum from Bliss Triumph tubers as compared with inoculum from the Teton and Red McClure varieties. The same was true for ring-rot severity as shown by the index figure. Ring-rot symptoms developed much earlier in the susceptible Bliss Triumph than they did in the partially-resistant Burbank and Red McClure. The plant symptoms of ring rot were so slight in the Teton variety that they were not included along with the other varieties shown in table 2.

The results obtained at Torrington in the comparison of inocula on the Bliss Triumph variety were similar to those obtained at Laramie. These data are recorded in table 3.

Although the Torrington plot was planted two days later than those at Laramie, ring-rot symptoms were visible a few days sooner at Torrington than at Laramie, due to differences in climatic conditions. However, the symptoms of ring rot were more visible and clear-cut at Laramie than at Torrington, partly because the plants at Laramie remained erect, whereas those at Torrington grew tall and lodged. Later they grew up again, for the most part, between the rows. Moreover, the factors were more favorable for the development of early blight at Torrington than at Laramie.

Microscopic examination of the slides showed that, as an average of all inoculations, far more bacteria were present in the Red McClure, Bliss Triumph and Burbank varieties than in the Teton variety. Furthermore,

TABLE 2—*The prevalence and severity of ring rot (plant symptoms) in the Red McClure, Burbank and Bliss Triumph varieties when inoculated with infected tubers of Bliss Triumph, Red McClure and Teton varieties and planted at the Agronomy Farm, Laramie, Wyoming, June 7, 1947.*

Varieties Used As Sources of Inocula	Date of Inspection	Varieties Inoculated and Resulting Ring Rot					
		Red McClure		Burbank		Bliss Triumph	
		Per Cent	Index*	Per Cent	Index*	Per Cent	Index*
Bliss Triumph	Aug. 18	0	0	0	0	100	1.5
Red McClure	" "	0	0	0	0	70	1.6
Teton**	" "	0	0	0	0	60	0.9
Bliss Triumph	Aug. 30	0	0	0	0	100	3.0
Red McClure	" "	0	0	0	0	85	3.0
Teton	" "	0	0	0	0	95	2.7
Bliss Triumph	Sept. 3	0	0	0	0	100	3.7
Red McClure	" "	0	0	0	0	95	3.3
Teton	" "	0	0	0	0	100	3.3
Bliss Triumph	Sept. 7	10	0.5	55	1.2	100	3.8
Red McClure	" "	0	0	38	0.8	95	3.4
Teton	" "	5	0.1	40	0.7	100	3.4

*Index figure calculated showing average severity of plant infection,—1 = slight, 5 = entirely killed.

**This variety was also inoculated but the ring-rot symptoms were so slight that it was not included in this table.

TABLE 3—*The prevalence and severity of ring rot (plant symptoms) in the Bliss Triumph potato variety when inoculated with infected tubers of the Bliss Triumph, Red McClure and Teton varieties and planted at Torrington, Wyoming, on June 9, 1947.*

Varieties Used As Sources of Inocula	Resulting Ring Rot (plant symptoms) in the Bliss Triumph Variety* at the Dates Inspected							
	Aug. 11		Aug. 29		Sept. 5		Sept. 11	
	Per Cent	Index**	Per Cent	Index**	Per Cent	Index**	Per Cent	Index**
Bliss Triumph	15	.12	100	1.9	100	2.3	100	2.5
Red McClure	5	.05	55	0.6	60	0.8	60	0.8
Teton	25	.22	85	1.3	90	1.5	90	1.8

*The Red McClure, Burbank and Teton varieties were also included but the results are not used here as the symptoms were indefinite, because of the prevalence of early blight.

**Index figure calculated showing average severity of plant infection.—1 = slight, 5 = entirely killed.

TABLE 4—*The relative prevalence of bacteria found in stem smears made from inoculated plants in each varietal test at the Agronomy Farm, Laramie,* 1947.

Varieties Used As Sources of Inocula	Relative Prevalence of Bacteria* from Stems of Four Potato Varieties				
	Teton	Red McClure	Burbank	Bliss Triumph	Average
Bliss Triumph	1.5	6.6	4.4	7.3	5.0
Red McClure	1.3	4.8	4.1	4.2	3.6
Teton	0.7	5.7	5.8	4.7	4.2
Average	1.2	5.7	4.8	5.4	

*Rating scale—1 = few bacteria, 10 = maximum number found.

as sources of inocula, the Bliss Triumph infected tubers produced, on the average, more bacteria in the stems of all inoculated varieties than either the Red McClure or Teton.

SUMMARY AND CONCLUSIONS

Experiments were conducted in 1946 and 1947 to determine whether or not ring-rot bacteria, *Corynebacterium sepedonicum,* from resistant potato seedlings and varieties were more pathogenic than those from susceptible varieties.

Bliss Triumph, Burbank, Red McClure and Teton tubers were inoculated, in all combinations, with inocula from ring-rot-infected tubers of the Bliss Triumph, Red McClure and Teton varieties. Resistant seedlings and susceptible varieties were also each used collectively as sources of inocula.

Under the conditions of the experiment, the percentage of ring-rot infection and the severity of infection caused by inocula from susceptible varieties was equal to, if not greater than, that caused by inocula from resistant varieties.

Plant symptoms developed much earlier in the Bliss Triumph variety than in the Burbank, Red McClure and Teton varieties. Symptoms of ring-rot were slight to absent in the latter variety.

In this experiment, the conditions at the Laramie Station (7165 feet elevation) were better adapted for ring-rot symptoms in the plants than at the Torrington Station (4104 feet elevation), although the plant symptoms took a few days longer to become visible at the higher altitude than at the lower one.

Microscopic examination of the slides showed that, as an average of all inoculations, far more bacteria were present in the Red McClure, Bliss Triumph and Burbank varieties than were present in the Teton variety. Furthermore, as sources of inocula, the Bliss Triumph tubers produced, on the average, relatively more bacteria in the stems of other varieties tested than either the Red McClure or Teton variety,

The results of these experiments show that ring rot bacteria infecting the Teton variety and ring rot-resistant seedlings were not more pathogenic than those carried by susceptible varieties, such as the Bliss Triumph.

RESEARCH ON HARVESTING, TRANSPORTATION AND STORAGE OF POTATOES — A REVIEW OF RECENT LITERATURE

J. M. LUTZ,[1] R. C. WRIGHT[2] and A. D. EDGAR[3]

Agricultural Research Administration, U. S. Department of Agriculture, Washington, D. C.

INTRODUCTION

As this review is necessarily very brief no attempt has been made to make it complete but it is believed that most of the significant work is included. For the most part this review dates from January, 1945, to the present, although occasionally an older publication is listed to provide continuity.

EARLY POTATOES

Handling and Transportation

Rose (36) has brought together most of the published and unpublished data on this subject. He points out that early potatoes are highly perishable and should be handled accordingly. Potatoes should be picked up within 15 to 30 minutes after being dug, especially on hot, dry, or windy days. Even after being picked up they should be brought from the field as soon as possible. An additional factor of great importance is to protect newly-harvested potatoes from the wind.

In general, a pyramid load in the refrigerator car is most desirable. Transit temperatures below 70°F are highly preferred. During warm weather some sort of refrigeration is highly beneficial. For short hauls pre-icing is the preferred method of shipment, and for long hauls

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[1]Physiologist.

[2]Physiologist, Division of Fruit and Vegetable Crops and Diseases.

[3]Agricultural Engineer, Division of Farm Buildings and Rural Housing, Bureau of Plant Industry, Soils and Agricultural Engineering.

one re-icing in addition is desirable. Pre-cooling alone has not been generally satisfactory commercially because the length of the pre-cooling period is too short to cool the load adequately. Fan-cars are superior to standard cars in refrigerated shipments.

Bacterial soft rot particularly during transit and on the markets has been a serious problem and has been given attention by a number of workers. Bennett (5) reports a soft rot epidemic in Great Britain which was associated with immature potatoes under conditions of lack of air, high temperature, moist atmosphere and pressure. Smith and Ramsey (38) reported that decay following lenticel invasion by bacteria was usually more serious in potatoes grown in wet or heavy soils. Eddins (14) also found that soft rot was very severe in fields where the soil remained water-logged for several days. Nielson (29) discovered that tubers when exposed for a period of a certain duration, reached a temperature of 113°F or higher (sub-lethal), and even though they exhibited no symptoms of injury, were more susceptible to bacterial soft rot than are potatoes not so exposed. This change appears to be reversible.

The elimination of conditions which predispose the early crop potatoes to decay and proper transit temperatures seem to be the most effective means of controlling losses from bacterial soft rot during marketing (36). Eddins (13) believes that driers should also reduce losses from soft rot.

Aside from decay, browning of skinned areas is an important source of loss (36). Benn (4) found that air movement during the period when the evaporative capacity of the atmosphere is high was the most important cause of browning. If this injury is severe, decay organisms may enter. Sunlight in itself had no effect on browning. Unskinned potatoes were seldom injured.

Storage

Although early potatoes are not generally stored in great quantities there are occasions when such storage is practiced, and unless properly done, considerable loss may occur. Kimbrough (24) found that curing for 1 to 2 weeks before storage at 35 to 40°F is recommended. A storage temperature of 40° was found to be superior to 35°. Katahdins kept much better at this temperature than did Triumphs. Lutz (27) reported that the storage of Triumphs under non-refrigerated conditions, such as a shed or basement resulted in very high losses. For a storage period of less than 3 months, storage at 50° was best although 40 to 60° was also quite satisfactory after the potatoes had been cured 4 days or longer at 60° prior to storage at 40°. For five months

storage-cured potatoes stored at 40° kept best, although immediate storage at 50° gave fair results.

Late Crop Potatoes

Vine Killers

Hoyman (20) found that in the absence of dew, dusts are not effective and Otis (30) does not recommend dusts in eastern Oregon because of low humidity.

Hoyman (20) discovered that the American Cyanamid Company Weed Killer A (37½-50 lbs. per 100 gals.) destroyed the weeds most rapidly. Dowspray 66 (2 gals. per 100 gals.) was more effective when 2 pounds NH_4SO_4 was added. The discoloration found in and near the vascular tissue of the tubers may or may not be a direct effect of the chemical, as mechanical cutting of the vines also produces this effect. The amount of discoloration was correlated with the rapidity of kill and was less when applications were made later in the season.

In Colorado, Kunkel (25) reported that all mechanical methods such as top pulling or cutting or undercutting of roots have disadvantages under some conditions and with some varieties. Dowspray 66 (2 gals. per 100 gals.) and Sinox (2 gals. per 100 gals. plus 10 pounds NH_4SO_4) when applied at the rate of 100 gallons per acre killed the tops in approximately 3 days and showed most promise. Both materials induced browning or discoloration at the stem end, but the general effect is not so clear for sometimes more discoloration occurs when vine killers are not used. Flaming is another possibility.

Harvesting

Bierly and Hardenberg (7) report that an inexperienced picker made about twice as many moves and picked up less than one-half as many potatoes as an experienced one.

Rest Period and Sprouting

Sprout Accelerators

No recent reports on materials newer than ethylene chlorhydrin or ammonium thiocyanate for breaking the rest period of potatoes have appeared.

A large scale test was conducted by Porter and Simpson (33). Ethylene chlorhydrin was used on more than 3000 bushels of Maine-grown potatoes in order to obtain early emergence in Florida for virus readings on the plants. By special variations in treatment for each variety they were able to get 95 per cent of the plants large enough for virus readings by the end of January.

A comparison of the ethylene chlorhydrin treatment with ammonium thiocyanate was made by Townsend (42). The yields after the latter treatment, were equal to or greater, than, the former. With

ammonium thiocyanate he could treat either freshly-cut or suberized seed pieces. They were dipped in a 0.75 to 1.0 per cent solution and allowed to stand 18 to 20 hours before planting. This treatment was considered easier and safer.

Pujals *et al* (34) have conducted experiments on the treatment of seed potatoes, first, with sprout inhibitors, and then with sprout accelerators. Two varieties were treated with the methyl ester of naphthalene acetic acid and ethyl naphthyl acetate. Previous to planting time they were treated with ethylene chlorhydrin to induce sprouting. Seed tubers thus treated did not yield so well as the checks, but the authors feel that with proper timing the yield should be equal to that of untreated tubers.

Sprout Inhibitors

In the field of sprout inhibitors the use of methyl ester of naphthalene acetic acid has proved the most satisfactory. In work reported by Daines and Campbell (12) the use of ⅔ to 1⅓ grams per bushel on Irish Cobbler or Katahdin varieties of potatoes proved more effective as a dust than when used on paper strips. Alban (2) working with (1) naphthalene-acetic acid, (2) indol butyric acid, and (3) naphthoxy-acetic acid and (4) 2,4-dichlorophenoxyacetic acid, with their salts and methyl esters, it was found that, in general, the methyl esters particularly of napthalene acetic acid were most efficient. Dust treatments were more effective than other methods used. In a study in consumer-packaging to reduce sprouting and also weight loss a combination of methyl ester of naphthalene acetic acid and Brytene 489A wax proved very effective. Smith (39) recommends a dust application as most effective in small lots used at the rate of .9 to 1.0 gms. methyl ester of naphthalene acetic acid per bushel. With amounts of more than 1000 bushels he recommends the use of a paint spray gun or aersol. For the spray gun he suggests a mixture of 1:1 with methyl alcohol, and with aersol he suggests using methyl chloride 1:9. In either case the application should be regulated so as to apply 1 gram of hormone per bushel. Kardos and Blood (23) found that maintaining an atmosphere of 10.5 per cent CO_2 and 13.6 per cent O_2 was fully as efficient as the methyl ester of naphthalene acetic acid. The retardation effect persisted to a considerable degree after removal to normal atmosphere. No "off" flavors were noted after cooking.

Chemical Composition and Cooking Quality

Ascorbic Acid Content

All workers report serious losses in ascorbic acid content during storage. Werner and Leverton (44) found that the ascorbic acid content varied with varieties, seasons, and within the same varieties. When the

vines were at the maximum vigor of growth the tubers averaged 35 to 55 mgs. per 100 gms. but when harvested a month later they had 30 to 40 mgs. per 100 gms. A higher amount of vitamin C was found in dry land culture than under irrigation. Less loss occurred from 50° to 70°F storage than at 40° to 50°. During cooking there was less loss in a minimum of water than when a large amount of water was used. Murphy (28) also found more vitamin C loss at low temperatures. Less loss occurred at 60° to 70°F than at 32° to 36°. Fifty degree storage seemed best because of less general deterioration. There was an overall average loss during storage from 22.7 to 6.3 mgs. per 100 gms. with ⅓ to ½ of this loss occurring the first month. Work of Roberts and Cameron (35) showed that during 6 to 7 months storage the loss of ascorbic acid amounted to 60 to 70 per cent. They also reported that the ascorbic acid content in individual varieties from different sections of the country was reasonably consistent.

Cooking Quality

Clark *et al* (10) pointed out the correlation between specific gravity of the raw product and the mealiness of the cooked product. As a result, in recent studies pertaining to the cooking quality of potatoes, considerable attention has been given to specific gravity.

LeClerg (26) ascertained that soil and climatic conditions did not influence the relationship between specific graviety and dry-matter content. Neither dry-matter nor specific gravity were significantly correlated with the weight of tubers.

In a study of the inheritance of dry-matter content it was discovered by Akeley and Stevenson (1) that the high density character seemed to be dominant over low density.

Caldwell *et al* (9) in their studies discovered that potato samples with high specific gravity gave a larger yield of the dehydrated product. These proved mealier and gave a generally better over-all quality than that from low specific gravity.

Briant (8) *et al* in a study of the physical properties of starch from potatoes showed a negative correlation between the number of starch granules below 0.02 mm. and the degree of mealiness. It was also shown that 16 per cent starch suspensions from the mealy potatoes jelled at a lower temperature and were less rigid than similar suspensions from the less mealy samples.

Discoloration in Cooking

Little or no definite information has appeared on the cause of discoloration of cooked potato products, except that greying or blackening is more prevalent in certain varieties and browning is correlated with

high reducing sugar. Bandemer *et al* (3) pointed out that discoloration increased with increase in moisture content and decrease in pH of the tuber. They further suggest that with the hydrolysis of sugar there is a combination with proteins to produce browning. Patton and Pyke (31) reported that the presence of reducing sugar in combination with amino acid was responsible for the browning of potato chips. Pollard (32), working in Great Britain, reported that blackening is not influenced by the pH of the soil. Site was an important factor and on good sites potash improved color. Wager (43) reported that stem-end blackening or greying was due to a single pigment—not melanin—whose color is influenced by pH.

"Off" Flavor

Benzene hexachloride shows promise of controlling wireworm but has a musty odor which flavors such food as potatoes (22).

Diseases

Physiological

Folsom (17) reports that internal mahogany browning which has been previously shown to be caused by continuous storage for several months at 32°F varies with variety. Predisposition to this disorder is inherited and the author suggests that for Northern potato growing regions the proper selection of parents for crosses can be helpful in developing varieties resistant to this defect.

Ross (37), in his work, found that stem-end browning which develops in storage varies in different strains of Green Mountains with the susceptible strain producing 2 to 7 times as much stem-end browning as the more resistant strains. Selections from susceptible strains were of no value. All Irish Cobbler lots were highly susceptible.

Wiant (45) investigating internal black spot of Long Island potatoes found that much of the disorder resulted from mechanical injuries sustained by pressure bruises during grading and sacking.

Investigations pertaining to the greening of potatoes (18) showed that potatoes greened faster at room temperatures than in a cool place. They also faded faster (in the dark) when warm than when cool. When exposed to the natural light in a cool greenhouse for two days it required a month or more in a warm dark storage to degreen them. When exposed to the light for a longer period, a period of several months was required. Cortical greening developed faster and faded less in Katahdins than in Chippewas and Green Mountains. When the greening is severe the green portion is replaced by red or brown when degreened.

Pathogenic

Bonde and Schultz (6) in their studies found that much of the late blight tuber rot in Maine resulted from harvesting while the fungus was still viable and before the plants were dead.

Thomas and Lane (41) in Colorado observed a condition where despite the fact that field losses from late blight were not heavy, the abnormal precipitation and late irrigation in September washed the inoculum to the tubers resulting in a 2 per cent storage loss. These conditions also caused more than 5 per cent storage loss because of "Western leak" caused by *Pythium* spp. and *Phytophthora* spp.

Cunningham and Reinking (11), investigating fusarium seed piece decay of potatoes on Long Island, found that the fusaria causing this decay gain entrance only through wounds. They will not enter through properly healed seed pieces.

Starr (40) has developed minimum requirements for the steam sterilization of burlap bags to kill potato ring-rot bacteria.

The description and method of control of potato diseases are discussed by Jensen and Levingston (21).

Storage Structures

At least five million bushels of late crop potatoes are stored in "shell cooled" storages which are adapted for use in the warmer section of the late-crop area. The principle of this method is to provide for circulation spaces in the walls and floor to allow cool air to pass around instead of through the bins. The high humidity thus maintained in the bins helps to reduce shrinkage and the low humidity elsewhere can be expected to prolong the life of the building (15).

Edgar (16) presents information and plans for storing potatoes in the parts of the U. S. where climatic conditions will permit good storage without refrigeration. For short storage periods—3 or 4 months or less —a minimum temperature of 50° is suggested. For longer storage a minimum of 40° but warming to 50°, two weeks before marketing, is recommended. Information regarding the construction and operation of these storage structures is also included.

Weight Losses in Storage

Alban (2) found that after 1, 4, 8 and 12 weeks storage at room temperatures, weight losses amounted to 1.2, 3.2, 6.4 and 11.6 per cent, respectively. Slightly less losses occurred in paper bags. Losses at room temperatures varied from 2 to 3 times as much as at cold storage.

Miscellaneous

Hannay and Hareide (19) have presented a bibliography on recent literature (1942-1946) pertaining to the marketing of fruits and vegetables.

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TESTS OF CUTTING KNIFE DISINFECTANTS AND CUTTING TECHNIQUES IN THE CONTROL OF RING ROT OF POTATOES[1]

GEO. H. LANE[2], R. KUNKEL[3], AND W. A. KREUTZER[4], [5]

Colorado Agricultural Experiment Station, Fort Collins, Colo.

INTRODUCTION

Ring rot, caused by *Corynebacterium sepedonicum* (Spieck. & Kott.) Skapt. & Burk., continues to be an important potential source of loss to growers of commercial potatoes, especially those who use non certified seed. Such seed lots may contain from a trace to 5 or more per cent of ring-rot infected tubers, sufficient to cause considerable loss of the crop unless precautions are taken to disinfect the cutting knife, sacks and planter. The cutting knife is probably the most important instrument in the dissemination of the causal agent to uninfected tubers since each seed piece cut makes contact with the knife while other potential means of spread such as infected cut tuber in a sack of healthy seed pieces, an infected planter pick, or a contaminated sack will contact only a relatively few seed pieces.

This paper reports results of investigations through two growing seasons on: (a) the effect of the addition of wetting agents on the disinfecting power of solutions of mercuric chloride and calcium hypochlorite, (b) the use of mercuric chloride or calcium hypochlorite for disinfection of the stationary double-edged knife (7), (c) the value of various disinfectants to prevent the spread of ring rot bacteria by the rotaary blade (2), (d) the comparative amount of ring rot transmissible by the surface of the cutting table under different knife disinfecting practices, and (e) the value of prompt submersion of inoculated seed pieces in a disinfectant solution as a method of ring rot control.

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[2]Associate Plant Pathologist.

[3]Horticulturist.

[4]Formerly Plant Pathologist. Colorado Agricultural Experiment Station.

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Field Tests 1946

Materials and General Methods

A supply of non certified Red McClure potatoes was divided into 33 lots of approximately 115 tubers each. From each lot 12 to 14 tubers were selected at random to supply 400 tubers which were planted without cutting to determine the amount of ring-rot infection present in this lot of seed. The remainder of each lot was used for tests of disinfection and transmission of the organism.

Knife blades or table surfaces were smeared with a ring-rot infected tuber as a source of inoculum at the beginning of each treatment and were recontaminated after each tenth tuber treated.

After treatment each lot was subdivided at random into 5 sub-lots of 40 seed pieces each and planted in 5 randomized blocks. Potatoes were cut from the 5th to the 8th of May and planted on the 9th and 10th of May.

Stand counts and the number of ring-rot infected plants in each plot were determined from the 29th of August to the 1st of September. The determination of ring rot infection was based on aerial symptoms plus the stem-ooze test (3).

Results and Discussion

Table 1 lists all the treatments employed, the average number of plants per plot at the end of the season, and the mean number of ring-rot plants per plot for each treatment. An analysis of variance applied to the stand data shows that there is no significant reduction in stand due to any treatment when compared to the mean of the ten plots of uncut seed. Consequently, the number of infected plants per treatment is used as a basis for statistical analysis of the disease data.

The Rotary Blade

The rotary blade was used to test the efficacy of various disinfectants, some of which were to be used on the stationary knife, since it has been established that spread of the ring-rot organism *via* the cutting knife can be prevented by disinfecting the rotating blade with boiling water or 0.2 per cent mercuric chloride (1), (4), (5), (8).

Included in the test were boiling water, 0.2 per cent mercuric chloride with and without Vatsol OT, Roccal and Hyamine 1622, each at concentrations of 1 per cent of the active ingredient, and BK in weight sufficient to yield 2,000 ppm of chlorine in solution. Other concentrations of chlorine ranging down to 25 ppm were also tested.

Many disinfectant materials are comparatively effective in reducing the spread of the ring-rot organism. However, a knife disinfectant can

TABLE 1.—*Stand and number of ring-rot plants — 1946 Field tests. 5-plot averages*

Knife	Knife Disinfectant	Direction[1] of Cut	Rate of Flow of Disinfectant	Ave. No. Plants per Plot	Ave. No. Ring-rot Plants per Plot
None	Uncut tubers		—	37.8 } 37.6	1.0 } 1.5
None	Uncut tubers		—	37.4 }	2.0 }
Rotary blade	None	—	—	38.2	36.0[0]
" "	Boiling water	—	—	39.0	1.2
" "	$HgCl_2$ 1-500	—	—	39.2	3.4
" "	$HgCl_2$ 1 500 + Vatsol OT[2]	—	—	39.0	4.2**
" "	Roccal (1-9)[3]	—	—	38.0	19.8[0]
" "	Hyamine 1622 1-24[4]	—	—	37.2	29.8[0]
" "	Cl 2000 ppm[5]	—	—	39.2	6.0**
" "	Cl 1000 ppm[5]	—	—	37.6	23.8[0]
" "	Cl 500 ppm[5]	—	—	38.4	30.0[0]
" "	Cl 250 ppm[5]	—	—	38.4	36.4[0]
" "	Cl 200 ppm[5]	—	—	38.4	33.6[0]
" "	Cl 150 ppm[5]	—	—	38.2	36.8[0]
" "	Cl 100 ppm[5]	—	—	38.0	33.0[0]
" "	Cl 50 ppm[5]	—	—	39.6*	38.0[0]
" "	Cl 25 ppm[5]	—	—	37.2	35.2[0]
Stationary Double-Edged	None	1-way	—	39.2	35.4[0]
" "	$HgCl_2$ 1-500	1-way	1 qt. per hr.	37.6	3.6*
" "	$HgCl_2$ 1-500	1-way	2 qt. per hr.	39.2	4.4**
" "	$HgCl_2$ 1-500	2-way	2 qt. per hr.	37.8	2.6
" "	$HgCl_2$ 1-500 + Vatsol OT[2]	1-way	2 qt. per hr.	39.0	3.0
" "	$HgCl_2$ 1-500 + Vatsol OT[2]	2-way	2 qt. per hr.	39.0	1.6
" "	Cl 2000 ppm[5]	1-way	2 qt. per hr.	38.2	14.0[0]

Knife	Knife Disinfectant	Knife Contaminated	Table Surface Contaminated	Ave. No. Plants per Plot	Ave. No. Ring-rot Plants per Plot
Rotary blade	$HgCl_2$ 1-500	no	yes	38.6	5.2**
" "	$HgCl_2$ 1-500	yes	yes	38.4	3.2
" "	Boiling water	no	yes[6]	38.8	9.4**
" "	Boiling water	no	yes[7]	38.6	38.0[0]
			Disinfectant Dip		
Stationary Double-Edged	None	yes	$HgCl_2$ 1-500[8]	37.0	15.8[0]
" "	None	yes	Cl, 2000 ppm[5,8]	39.0	18.6[0]
Difference required for significance—					
Comparing 5-plot means with 10-plot mean of whole tuber checks					
5 per cent point (Odds 19:1)				1.62	1.96
1 per cent point (Odds 99:1)				2.15	2.61
Comparing any pair of 5-plot means					
5 per cent point (Odds 19:1)				1.88	2.26
1 per cent point (Odds 99:1)				2.48	3.01

[0]Number of ring rot plants obviously excessive, hence not included in analysis of variance.
*Exceeds mean of whole-tuber checks, odds 19:1.
**Exceeds mean of whole-tuber checks, odds 99:1.
[1]1-way—all tubers pass the knife blade in one direction; 2-way—alternate tubers pass knife blade in opposite directions.
[2]Vatsol OT85, (sodium dioctyl sulfo-succinate) 1 teaspoon per gallon.
[3]Mixture of alkyl-dimethyl-benzyl ammonium chlorides—1 per cent of active ingredient.
[4]Di-isobutyl phenoxy ethoxy dimethyl benzyl ammonium chloride—1 per cent of active ingredient.
[5]Commercial BK solution, tested with Taylor Chlorine slide colorimeter.
[6]Metal plate above boiling water, hot.
[7]Metal plate, not over boiling water, cold.
[8]Cut seed pieces immersed immediately on cutting.

be said to give satisfactory control of ring rot only if sample lots of potatoes cut while using that disinfectant develop no more ring-rot plants than the uncut tubers.

Of the disinfectant materials tested on the rotary blade all except boiling water and 0.2 per cent mercuric chloride permitted a significant increase in the number of ring-rot plants when compared with the uncut tubers. The number of ring-rot plants was obviously excessive in lots cut while using chlorine concentrations below 2000 ppm or the quaternary ammonium compounds, Roccal and Hyamine 1622. The analysis of variance applied to the remaining treatments showed the two treatments, mecuric chloride (0.2 per cent) plus Vastol OT and 2000 ppm of chlorine to be unsatisfactory as a control in this test.

It may be noted that the number of ring-rot plants in cut-seed lots is rather consistently greater than in the uncut tuber lots even though the differences are often not statistically significant. This may have resulted from contamination of fresh cut seed-piece surfaces by ring-rot bacteria from infected seed pieces mixed with the healthy ones in sacks or boxes after cutting. This uncontrolled source of statistical error would tend to increase the amount of ring rot in cut seed trials beyond the amount normally carried by the seed source.

The Stationary Double-Edged Knife

Tests, in 1945 (5), of the stationary double-edged blade revealed an anomalous situation in that an increase in rate of flow of the disinfectant from one quart to two quarts per hour decreased the effectiveness of ring-rot control. It appeared that there might be two possible explanations of this tendency: (1), the possibility that the surface tension of the liquid would tend to draw it into flow lines as the volume increased and hence leave part of the blade uncovered; and, (2), that since all the tubers in the test were of 2-seed-piece size and were cut in the same direction across the knife they would tend to push the disinfectant aside, and perhaps, build up starch deposits which would deflect the flow away from the edge of the knife. Means of testing these hypotheses were accordingly devised, one set to compare the effect of one-way and two-way cutting, and another set to test the effect of the addition of Vatsol OT, a wetting agent, to the disinfectant on both one- and two-way cutting at the higher rate of flow of disinfectant.

Those lots in which the tubers were cut in alternate directions across the knife were not significantly different from the uncut tubers in the number of ring rot plants produced. There was also no significant difference in number of ring rot plants between lots cut with and without the addition of the wetting agent to the disinfectant. However, the lots

which were cut without the wetting agent in the disinfectant differed significantly from the uncut tubers in number of ring rot plants whereas those cut after the wetting agent was added did not. This fact suggests that the addition of the wetting agent improved the effectiveness of ring rot control on this knife.

Table Surface Contamination

Tests, in 1945 (5), of the amount of spread of the ring-rot organism by contact of the cut surface of the seed piece with contaminated table surfaces adjacent to the cutting knife revealed a significant increase in the number of ring-rot plants though the amount was smaller than expected. In these tests the rotary blade on which the tubers were cut was disinfected with 0.2 per cent mercuric chloride presumably leaving a film of the disinfectant on the seed pieces.

Tests were included in 1946 in which seed pieces cut on the rotary blade revolving in 0.2 per cent mercuric chloride or in boiling water were exposed to infection by rubbing the cut surfaces over metal plates smeared with inoculum from a ring-rot infected tuber. For one lot of seed pieces cut using boiling water as the disinfectant, the inoculum was spread over a hot metal plate heated by steam rising from the tank of boiling water; whereas for a second lot the inoculum was spread on a similar metal plate not so heated. The same cold metal plate was used to inoculate the seed pieces cut using mercuric chloride as the knife disinfectant. All except one of the lots so treated developed excessive amounts of ring rot. Both lots cut on the knife revolving in 0.2 per cent mercuric chloride developed significantly less infection than those for which the knife disinfectant was boiling water and one of these was not significantly different from the uncut tuber controls.

Immersion of Seed Pieces

In early tests at this Station attempts to control ring rot by dipping seed pieces in mercuric chloride solution after cutting them on a contaminated knife were made without success. In these tests a moderate amount of time elapsed between cutting and immersion. In the present tests two lots of tubers were cut on a contaminated double-edged knife without disinfection, the seed pieces being dropped directly from the knife into the disinfectant (0.2 per cent mercuric chloride in one test, 2000 ppm of chlorine in the other).

Ten tubers were cut and dropped into the disinfectant in quick succession and then immediately removed, the whole operation requiring approximately 40 seconds, after which the cutting blade was re-contamin-

ated and another 10-tuber lot was treated until a total of 100 tubers had been cut.

Plots from both treatments ($HgCl_2$ and Cl) showed an obviously excessive number of ring-rot plants.

Field Tests—1947

Materials and General Methods

Following the same technique as described above 16 lots of non-certified Red McClure potatoes were separated, two consisting of 200 tubers each to be planted without cutting, the remaining 14 lots consisting of 100 tubers each for transmission and disinfection tests on the rotary blade and the double-edged stationary knife. Disinfectants tested on the rotary blade were 0.2 per cent mercuric chloride and chlorine from calcium hypochlorite at 5000 ppm. Both disinfectants were used with and without Triton X300, a wetting agent. The two mercuric chloride solutions were also used to disinfect the double-edged stationary knife with two styles (directions) of cutting and at two rates of flow. Knife blades were contaminated in the same way as previously described. Tests of both cutters were made without disinfection to ascertain the efficiency of the inoculation technique. Seed pieces of all lots were assigned at random to five sub-lots and were planted in 5 randomized blocks. Chlorine solutions were tested with a Taylor Chlorine Slide Colorimeter to determine the amount of chlorine present. The tubers were cut on the 14th and 15th of May and planted on the 17th. Stand counts and the number of ring-rot plants per plot were determined from the 28th to the 30th of August.

Results and Discussion

Table 2 shows summaries of the data obtained from this plot. An analysis of variance of the data on stand shows no significant differences between treatments. Since the amount of ring-rot infection revealed in the uncut tubers was extremely low the degree of infection was treated as a Poisson variable and the formula

$$P_x = \frac{e^{-Np}(Np)^x}{x!}$$

(6) was used to determine the maximum number of ring-rot plants permissible in a treatment population corresponding to a probability of .01 that the ring rot present was the result of chance. In the range of populations per treatment involved in this experiment and with approximately 0.5 per cent ring-rot infection in the seed, a total of four ring-rot plants in any treatment is excessive, corresponding to a probability of .05; a total of five ring-rot plants is excessive, corresponding to a

TABLE 2.—*Stand and number of ring-rot plants—1947 field tests of the rotary and stationary double-edged knife*

Knife	Knife Disinfectant	Rate of Flow of Disinfectant	Direction of Cut[1]	Ave. No. of Plants per Plot (5-Plot Ave.)	Total No. Ring-Rot Plants (5-Plots)
None	Uncut tubers	—	—	39.4 } 39.0	0.0
None	Uncut tubers	—	—	38.6 }	2.0
Rotary blade	$HgCl_2$—1-500	—	—	38.2	0.0
Rotary blade	$HgCl_2$—1-500 + Triton X300[2]	—	—	39.4	1.0
Rotary blade	Cl 5000 ppm[3]	—	—	39.8	1.0
Rotary blade	Cl 5000 ppm + Triton X300	—	—	38.8	1.0
Rotary blade	None	—	—	39.6	157.0**
Stationary Double-edged	$HgCl_2$ 1-500	1 qt. per hr.	1-way	39.0	1.0
" "	$HgCl_2$ 1-500	1 qt. per hr.	2-way	39.6	1.0
" "	$HgCl_2$ 1-500	2 qt. per hr.	1-way	39.4	1.0
" "	$HgCl_2$ 1-500	2 qt. per hr.	2-way	37.8	0.0
" "	$HgCl_2$ 1-500 + Triton X300	1 qt. per hr.	1-way	39.8	5.0**
" "	$HgCl_2$ 1-500 + Triton X300	1 qt. per hr.	2-way	38.8	0.0
" "	$HgCl_2$ 1-500 + Triton X300	2 qt. per hr.	1-way	39.2	0.0
" "	$HgCl_2$ 1-500 + Triton X300	2 qt. per hr.	2-way	39.0	0.0
" "	None			38.6	81.0**
Difference required for significance—					
Comparing 5-plot means with 10-plot mean of uncut tubers					
	5 per cent point, Odds 19:1			1.24	
	1 per cent point, Odds 99:1			1.65	
Number of ring-rot plants required for significance					
(Poisson distribution)	5 per cent point, Odds 19:1				4.0
	1 per cent point, Odds 99:1				5.0

**Exceeds the uncut tuber controls, odds 99:1.
[1]1-way, all tubers pass the knife in one direction; 2-way, alternate tubers pass the knife in opposite directions.
[2]Sodium salt of alkylated aryl polyether sulfate, ½ ml. per gallon.
[3]Commercial BK solution, tested with Taylor Chlorine Slide colorimeter.

probability of .01. In this test the number of ring-rot plants in only the inoculated but non-disinfected lots and one other, mercuric chloride plus Triton 300, 1 quart per hour with one-way cutting on the stationary double-edged knife, exceeded the number of ring-rot plants in the uncut seed lots at the 1 per cent level of significance (odds 99:1).

Summary and Conclusions

Tests of the disinfection of the double-edged stationary knife with 0.2 per cent mercuric chloride indicated that the addition of a wetting agent to this disinfectant probably results in more effective ring-rot control on this knife.

Disinfectant tests on the rotary blade showed satisfactory ring-rot control through the use of 5000 ppm of chlorine, 5000 ppm of chlorine plus Triton X300, 0.2 per cent mercuric chloride, 0.2 per cent mercuric chloride plus Triton X300, or boiling water. Unsatisfactory disinfection resulted from the use of (1) the quaternary ammonium compounds Hyamine 1622 and Roccal, each at 1 per cent of the active ingredients, (2) 0.2 per cent mercuric chloride plus Vatsol OT and (3) calcium hypochlorite solutions containing chlorine in concentrations of 2000 ppm or less.

Tests were made of the dissemination of ring-rot bacteria by contact of the fresh-cut seed-piece surface with a contaminated table surface after using mercuric chloride or boiling water as a knife disinfectant. All test lots, with the exception of one, showed excessive numbers of ring-rot plants.

Prompt immersion of seed pieces in disinfectant solution (0.2 per cent mercuric chloride or 2000 ppm of chlorine) after inoculation with contaminated cutting knife materially reduced the number of ring-rot plants although ring rot resulting from both treatments was far in excess of that from uncut tuber lots.

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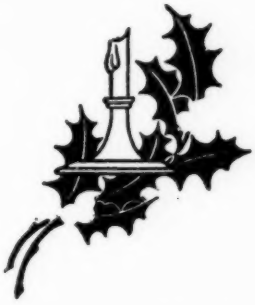

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